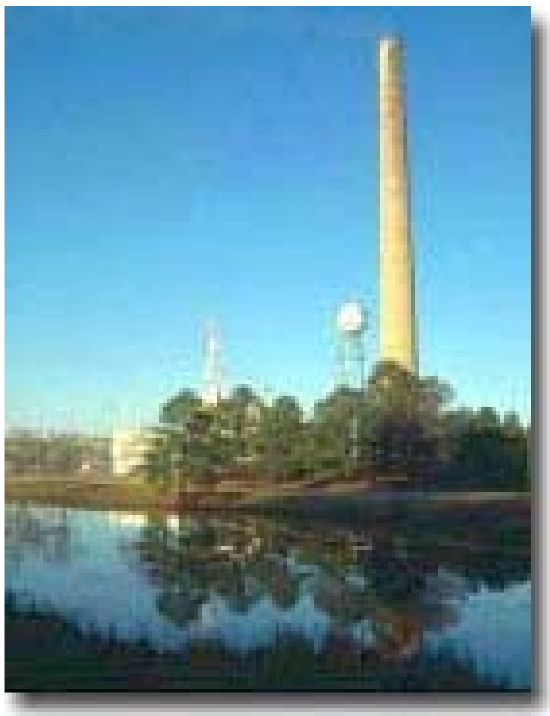
Mercury Control Technology
R&D Program Review Meeting

U.S. Department of Energy • Office of Fossil Energy • National Energy Technology Laboratory

Summary of Proceedings:
Mercury Control Technology
R&D Program Review Meeting



August 12-13, 2003
Pittsburgh Airport Hyatt Hotel
Pittsburgh, Pennsylvania

Sponsored by
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INTRODUCTION

The U.S. Department of Energy's National Energy Technology Laboratory (DOE/NETL) sponsored a *"Mercury Control Technology R&D Program Review Meeting"* on August 12-13, 2003 in Pittsburgh, PA. As part of the Innovations for Existing Plants (IEP) program, DOE/NETL is conducting a broad spectrum of research projects ranging from bench-scale through field testing that are focused on the development of cost-effective mercury control technology for coal-fired power plants. The research also includes the impact of selective catalytic reduction (SCR) on mercury oxidation, the measurement of mercury in stack plumes, the characterization of mercury and other metals in coal byproducts, and the development of technologies to separate mercury sorbents from flyash. The meeting provided an up-to-date summary of the status and progress of each of the mercury research and development (R&D) projects being carried out as part of the IEP program. The meeting was attended by over 160 participants including representatives from local, state and federal government environmental agencies; electric utility and coal industry; industry associations; technology vendors; and both private and university researchers. There were 27 participants from the electric utility industry representing 19 companies.

BACKGROUND

Mercury exists in trace amounts in fossil fuels (e.g., natural gas, oil, and coal), vegetation, crustal material, and waste products. Through combustion or natural processes, mercury vapor can be released to the atmosphere, where it can drift for a year or more, spreading with air currents over vast regions of the globe. In 1995, an estimated 5,500 tons of mercury was emitted globally from both natural and anthropogenic sources. Coal-fired power plants in the U.S. contributed less than one percent of the total. Research indicates that high levels of mercury pose both human health and environmental risks, and fish consumption is the primary pathway for human and wildlife exposure.

Coal-fired power plants emit an estimated 48 tons of mercury annually, or about one-third of the total U.S. anthropogenic mercury emissions. The U.S. Environmental Protection Agency (EPA) in December 2000 determined a need to regulate mercury emissions from coal-fired power plants because of the "plausible link" between emissions of mercury from these plants and the bioaccumulation of mercury in fish. As a result, EPA has begun development of a maximum achievable control technology (MACT) standard to regulate mercury emissions of power plants. The final MACT regulation is to be issued by December 2004 and compliance would be required by December 2007. Parallel to the MACT process, President Bush introduced the Clear Skies Initiative in February 2002 that would call for a phased-in reduction in mercury from power plants beginning in 2010 and that has been embodied in the Clear Skies Act of 2003. Several other multi-pollutant control legislative bills have been introduced in the 108th session of Congress calling for the regulation of coal-fired power plant mercury emissions.

The challenges of removing mercury from a diverse fleet of more than 300 Gigawatts of coal-fired generating capacity are many. Complicating factors include the type of coal being fired, the design of the boiler and combustion system, the type of downstream conventional control equipment in place, the chemical form of the mercury, the properties of the fly ash, and the relatively low concentration of mercury in flue gas. Today, no single technology can cost-effectively provide add-on mercury control for all plant configurations and fuel types.

In response to these challenges, DOE/NETL has been carrying out a comprehensive, integrated R&D program since the early 1990s to develop low-cost mercury control technologies for coal-fired power plants. Early efforts were directed at characterizing power plant mercury emissions and on laboratory and bench-scale control technology development. The current program is directed at full-scale field-testing of mercury control technologies as well as continued bench- and pilot-scale development of a number of novel control concepts. Field-testing of sorbent injection at four coal-fired power plants and testing at two plants of a proprietary liquid reagent to enhance mercury capture in wet flue gas desulfurization systems have recently been completed. A second phase of longer-term field-testing will be initiated in 2003.

The bench and pilot-scale research includes alternative sorbent technologies, oxidation systems, and methods to enhance mercury capture with conventional particulate, SO_2, and NOx control equipment. The program also involves fundamental and computational science, an evaluation of the fate of mercury in coal utilization by-products (e.g., fly ash), and the study of the emission, transport, and transformation of mercury in power-plant plumes. As such, the program provides high-quality scientific and technical information on present and emerging environmental issues for use in regulatory and policy decision making.

While our understanding of the formation, distribution, and capture of mercury from electric-utility boilers has evolved, further research is needed in order to allow the Nation's electric utilities to respond to future mercury regulations in a cost-effective manner. DOE/NETL will continue its partnership with industry and academia to further the development of advanced mercury control technology and to provide the scientific and technical knowledge needed to help formulate sound regulatory policy.

MEETING OUTLINE

Thomas J. Feeley III, NETL Product Manager for the Environmental and Water Resources Program, hosted the meeting and provided participants with a brief introduction to the meeting logistics and program content. A welcome presentation was provided by Carl O. Bauer, NETL Associate Director for the Office of Coal and Environmental Systems. Mr. Bauer's comments included an overview of DOE/NETL programs and background information on how pending mercury regulation of coal-fired power plants is driving mercury control technology R&D efforts. Overviews of the mercury R&D programs for DOE/NETL, EPRI, and EPA were provided by Scott A. Renninger, George R. Offen, and James D. Kilgroe, respectively.

The remainder of the two-day meeting was devoted to 30 minute presentations for 21 DOE/NETL-sponsored mercury control technology R&D projects, including three

presentations that summarized NETL in-house mercury R&D efforts. The presentations were made by the lead project researchers and included a description of the project, key results to date, and future direction. In addition, there were ten poster presentations on display during the meeting. A copy of the presentations and posters are available under the "Reference Shelf" on the DOE/NETL website at:
http://www.netl.doe.gov/coalpower/environment/index.html

PRESENTATIONS

Field Test Program to Develop Comprehensive Design, Operating and Cost Data for Mercury Control
Michael D. Durham, ADA Environmental Solutions LLC

Full-Scale Testing of Enhanced Mercury Control Technologies for Wet FGD Systems
George A. Farthing, McDermott Technology Inc.

Long-term Operation of a COHPAC System for Removing Mercury from Coal-Fired Flue Gas
C. Jean Bustard, ADA Environmental Solutions LLC

Mercury Control with the Advanced Hybrid Particulate Collector
Stanley J. Miller, Energy & Environmental Research Center

Mercury Removal in a Non-Thermal Plasma Based Multi-Pollutant Control Technology for Utility Boilers
Christopher R. McLarnon, Powerspan Corp.

Pilot Testing of Oxidation Catalysts for Enhanced Mercury Control by Wet FGD Systems
Gary M. Blythe, URS Corporation

The CONSOL/Allegheny Pilot Plant Study of Low-Temperature Mercury Capture with an Electrostatic Precipitator
Richard A. Winschel, CONSOL Energy Inc.

Pilot-Scale Research at NETL on Mercury Measurement and Control
Andrew Karash, U.S. Department of Energy, National Energy Technology Laboratory

Novel Techniques for Mercury Control
Evan J. Granite and Henry W. Pennline, U.S. Department of Energy, National Energy Technology Laboratory

Assessment of Low-Cost Novel Sorbents for Coal Fired Power Plant Mercury Control
Trevor Ley, Apogee Scientific, Inc.

Mercury Control with Calcium-Based Sorbents and Oxidizing Agents
Thomas K. Gale, Southern Research Institute

Preliminary Field Evaluation of Mercury Control Using Combustion Modifications
Vitali Lissianski, GE Energy & Environmental Research Corp.

Oxidation of Mercury Across SCR Catalysts in Coal-Fired Power Plants Burning Low-Rank Fuels
Constance Senior, Reaction Engineering International

Mercury Control Technologies for Electric Utilities Burning Lignite Coals
John H. Pavlish, Energy & Environmental Research Center

Evaluation of Mercury Emissions from Coal-Fired Facilities with SCR-FGD Systems
Shiaw C. Tseng, CONSOL Energy R&D

Evaluation of Mercury Speciation at Power Plants Using SCRs for NOx Control
Dennis L. Laudal, Energy & Environmental Research Center

Speciation and Attenuation of Arsenic and Selenium, and Fate of Mercury in Coal Combustion Products
Ken Ladwig, EPRI

Direct Measurement of Mercury in Power Plant Plumes
Leonard Levin, EPRI

The Evolution of Mercury from Coal Combustion Materials and By-Products
Allyson M. Schwalb, CONSOL Energy Inc.

NETL's Coal By-Product Characterization Research
Ann G. Kim, U.S. Department of Energy, National Energy Technology Laboratory

Mercury Impacts on By-Products
Debra F. Pflughoeft-Hassett, Energy & Environmental Research Center

POSTERS

Evaluation of the Emission, Transport, and Deposition of Mercury from Coal Based Power Plants in the Ohio River Valley Region
Kevin Crist, Ohio University

Mercury Deposition Monitoring at the Holbrook Site, Greene County, PA
Robinson P. Khosah, Advanced Technology Systems, Inc.

Assessing the Mercury Health Risks Associated with Coal-Fired Power Plants: Impacts of Local Deposition
Terry Sullivan, Brookhaven National Laboratory

Critical Review of Mercury Chemistry
C. David Livengood and Marshall H. Mendelsohn, Argonne National Laboratory

Computational Approaches to the Development of Advanced Mercury Control Technologies
Jens I. Madsen, Fluent Inc.

Fate of Oxidized Mercury in Biologically Regenerated NOx Scrubber Liquor
Richard W. Hammack, U.S. Department of Energy, National Energy Technology Laboratory

"Longer-Term" Mercury Emission Variability
Dennis L. Laudal, Energy & Environmental Research Center

Processing and Reuse of Activated Carbon Used to Adsorb Mercury from Power Plant Flue Gases
Thomas Weyand, Pittsburgh Mineral and Environmental Technology

Injecting Gas Oxidants to Oxidize Elemental Mercury for the Control of Its Emission from Coal Power Plants
Ted Chang, Lawrence Berkeley National Laboratory

Multi-Pollutant Control Using Membrane-Based Up-Flow Wet Electrostatic Precipitation
David J. Bayless, Ohio University

MEETING OBSERVATIONS

While much has been learned over the last ten years regarding the control of mercury emissions from coal-fired power plants, there is still much uncertainty and many unresolved questions. It is clear that continued mercury control technology R&D is necessary in order to provide the U.S. coal-fired power plants with predictable, reliable and cost-effective means to achieve compliance with pending mercury emission regulations. Based on the project presentations, question and answer sessions, posters, and informal break-time discussions, a few general observations can be drawn from the two-day meeting:

- Coal properties and process conditions can significantly impact the potential mercury capture performance of mercury control technologies. The effectiveness of mercury capture under varied conditions (e.g., mercury speciation, flue gas temperature, and flue gas constituents such as fly ash, unburned carbon, chlorine, sulfur, NOx, and calcium) require continued investigation.

- The speciation of mercury in coal combustion flue gas remains an important variable affecting control technology performance. Mercury speciation appears to be a function of both coal properties and plant design and operating factors.

- The chemical form of oxidized mercury in coal combustion flue gas is also important due to differences in solubility that may affect the ultimate removal of mercury in a downstream wet FGD system. Oxidized mercury could be present as various chemical compounds with oxygen, chlorine, nitrogen, or sulfur.

- Currently, no single technology can cost-effectively provide add-on mercury control for all generating configurations or all fuel types. Activated carbon injection (ACI) has shown the most promise as a near-term mercury control technology and has been successfully demonstrated in a few short-term applications. However, the range of effectiveness depends on coal type and plant configuration. More long-term evaluation is necessary to determine realistic cost and performance estimates for various plant arrangements.

- The co-benefit capture of oxidized mercury by wet FGD systems has been successfully demonstrated. However, potential re-emission of a portion of the oxidized mercury to elemental mercury within the wet FGD absorber may reduce overall capture in some applications.

- Although mercury oxidation across NOx SCRs has been demonstrated, it appears to be highly variable depending on coal properties and SCR catalyst factors including type, sizing (space velocity), and age.

- For all of the mercury control technologies, uncertainties remain regarding the capture effectiveness with various coal-rank and existing pollution control device configurations, balance-of-plant impacts, and by-product use and disposal.

- The accuracy and precision of mercury measurements using both the manual wet chemistry Ontario Hydro method and several different mercury CEMs have demonstrated significant variability and complicate drawing conclusions from the limited field-testing conducted to date.

- Although improvements are being made, mercury CEMs have not yet demonstrated long-term reliability necessary for use as regulatory compliance tools.

- For utilities that sell their ash, increase in carbon content (or the addition of other chemical compounds) may negatively affect their ability to market the product, and they may incur additional disposal costs.

- Another issue is the impact that increased mercury in coal combustion by-products may have on disposal requirements under the Resource Conservation and Recovery Act (RCRA). There is the potential that increased partitioning of gas-phase mercury to the solid by-products could result in EPA revisiting the current exemption (the Bevill Exemption) of coal utilization by-products (CUBs) from regulation as hazardous waste. In 2001, more than 121 million tons of CUBs were generated. The costs of managing even a portion of those by-products as hazardous wastes would be significant.

FUTURE R&D NEEDS

The following is a summary of the responses to the question asked of the meeting participants -- what additional research should we (DOE/NETL) be doing in the area of mercury control?

- Short-term, (e.g., 1 week) tests of near-term controls on a larger number of plants than possible in the long-term phase 2 program. Need better assurance that performance is applicable across-the-board for given fuel/pollution controls.
- More basic or fundamental research especially in the area of mercury measurement and mercury sorbent surface chemistry.
- Mercury releases at front end of plant during grinding and handling.
- A lot of work is being done with fabric filter arrangements. Need more with just ESP's or ESP's/FGD arrangements. More on CEMS support.
- Look into pre-combustion mercury controls. Consider the geology and source of coal mines—draw on studies by Bob Finkleman.
- Reburning—multi-pollutant control for NO_x and Hg. In general, DOE should be funding more pilot-scale work on mercury speciation fundamentals and on mercury speciation fundamentals and on mercury removal technologies in pilot-scale facilities. Pilot-scale offers results directly applicable to full-scale plants and also provides well-controlled and reproducible conditions.
- Ash conditioning research to develop technologies for moderate temperature (regenerative air heaters) mercury removal by fly ash.
- FGD re-emissions in conjunction with Hg oxidation catalysts. It seems that a pilot scrubber would be appropriate since ox cat systems are pilot. A pilot scrubber would also allow testing of in- and ex-situ systems.
- Developing mercury control for other energy sources (municipal solid waste combustion, etc.) Impact of mercury control technologies on by-product uses. Mercury analysis, instrumentation, CEMs with speciation. Microbiological studies of mercury fate and transport in soil/groundwater environments (along with other toxic metals).
- A thorough understanding of flue-gas chemistry is needed. What are the actual oxidized species?
- At plants which employ injection mercury controls, we do not seem to see mercury which has been removed from flue gas stream showing up in the fly ash/bottom ash waste streams. Why not? Where does Hg removed from flue gases go?
- Large-scale sorbent injection in HS-ESP. Sorbents without impact on fly ash utilization in concrete. Halogen impregnated carbon or sorbent.
- Mercury speciation formation combustion understanding:

    - can we control combustion to more effectively produce oxidized mercury for capture
    - Fuel based additive control for oxidation/particulate formation easing capture

- More research needs to be done to address the final fate of the mercury and reuse/recovery of the carbon absorbents, mercury, and all associated coal combustion products.

- Expand the area of application to include natural gas. Many facilities might consider changing from coal to a mixed feed. There is a significant quantity of mercury in some natural gas.

- I would like to see more emphasis on the economics of the various mercury removal technologies. Utilities are not going to buy the most effective technologies; rather they are going to buy the most cost effective solution that still meets their desired mercury removal rates. Economic analysis, in addition to technical analysis, is important in getting these technologies commercialized.

- To better understand variability of mercury in coal, it is necessary to better understand the genesis of the major coal fields. To accomplish this, we need to hear from the geology side of the science; knowledgeable geologists could potentially provide valuable insights as to age/structure/creation processes associated with the major coal fields that may be involved in how Hg was incorporated into these carbon matrices many eons ago.

- Is work planned to evaluate lime spray dryer FGD systems (as used out west) and mercury? Does this material exhibit any sorbent characteristics that might make the high LOI ash (~8%) which is captured with the FGD material? It might have potential.

- Cost/benefit analyses that address the various control technologies, their impact on the marketability of coal combustion byproducts including fly ash and scrubber gypsum and disposal costs. None of the technologies address fluidized bed combustion units – what about Hg control in them? And other clean coal technologies?

- Effective methods of on-line Hg^{o} and Hg^{2+} measurements (interferences, sensitivities of PS Analytical system, for example); closed-loop systems for controlling mercury emissions.

- Better quantification of global mercury emissions; because U.S. emission reductions would be offset by increased emissions from other countries- China, India, etc. Accordingly, a global Hg management program would be needed to deal with the “perceived” Hg problem in the U.S. (i.e. to support the fact that even 100% control of U.S. emissions would not make any difference in Hg deposition and fish impacts).

- Expand the CONSOL Study of low-temperature Hg capture with an ESP. Provide additional support for the study of photochemical reaction of Hg with flue gas constituents. Expand the work with calcium-based sorbent with Na_2S_4 injection.

- Relating to sorbent injection:
    - performance impacts
    - by product impacts
    - cost-related issues
    - materials of construction impacts
- More on mercury – flue gas effects. Look at effect of SO_3 on carbon sorbents.
- Development and full scale testing of novel, low cost sorbents.
- Full-scale demonstration tests of the most promising of the newly developing mercury control technologies.
- More investigation of the fundamental science of mercury reactions and capture. Establish and support test facility for rapid screening of new concepts at pilot scale. Put more emphasis on true multi-pollutant control technologies – most approaches are just integrations of separate processes.
- Full-scale demonstrations of impregnated PACs, esp. on PRBs. Methods for identifying individual oxidized Hg species. Non-Toxecon solutions for plants with hot-side ESPs. Examination discriminating between in-flight and ESP-deposition Hg-removal Examination of effects of different sorbent injection parameters (+ modeling?)

ADDITIONAL INFORMATION

For additional information on NETL's mercury control R&D program, please contact:

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OR

Visit NETL's Environmental and Water Resources Website at:
http://www.netl.doe.gov/coalpower/environment/